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UAVs and PATIENT MOVEMENT

by

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Abstract

Timeliness of care on the battlefield is often times the difference between life and death. The time it takes evacuation personnel to transport wounded to higher levels of care has evolved significantly the past 200 years. This paper takes an in depth look at the evolution of patient movement and the utilization of advanced technologies from to ultimately decrease the time to care. Future operating environments have the potential to limit the traditional patient movement systems that have proven to be successful during recent conflicts in Iraq and Afghanistan. In addition, Anti-Access and Area Denial (A2/AD) capabilities of near peer adversaries present a potentially complex environment for patient movement and aeromedical evacuation operations. The next logical step in the evolution of utilizing new technologies to decrease time to care for wounded Soldiers, Sailors, Airmen and Marines lies in the use of Unmanned Aerial Vehicles (UAVs) for patient transport. An important aspect of the evolution is predicated on the dedication of sufficient means and research to ensure combatant commanders are provided with this additional lifesaving toolset prior to the specific need for it arises.

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Introduction

Since man first took flight, employing aircraft for the movement of medical patients has increasingly become a more regular occurrence. Even before the advent of heavier-than-air powered flight, hot air balloons evacuated wounded during the Franco-Prussian War. Many medical professionals recognized the need to get the injured and ill to care quickly and seized upon aircraft as a technology to accomplish this action. Today, the catch-all term for this need for rapid care is termed the “Golden Hour,” (an established standard to get all wounded troops to a higher level treatment facility within 60 minutes). To meet this standard, the complexity and capabilities of the current wartime medical transport system have increased exponentially. A major component of improvements in this areas has been the adoption of new technologies. The military has a long history of utilizing and adapting new technologies that can be used to decrease the time to treatment for wounded personnel. After all, time is the crucial determining factor and is often the deciding element between life and death. An examination of the evolution of patient movement to make the case for taking the next logical step, the utilization of Unmanned Aerial Vehicles (UAVs) follows. This logical progression of UAV utilization starts with its employment for Class VII resupply (i.e., blood) and easily evolves toward full scale patient movement using advanced remote tele-monitoring and tele-surgical systems. In addition to the temporal advantages, many factors must be considered such as the ethical, operational, and clinical aspects of moving patients with UAVs well in advance of actual implementation. Patient movement using UAVs is not meant to replace the current system, but serve as an additional tool for combatant commanders to employ under various wartime and disaster relief conditions.

As early as 1910, De Mooy, the Chief of Dutch Medical Service, conceptualized air transport of combat casualties utilizing not just ground and rail capabilities but aircraft as well.¹

Prior to that, although substantial evidence is lacking, hot air balloons were used to transport patients during the Franco-Prussian wars. Since that time, the evolution of patient transport on and around the battlefield has been fast and furious. Timeliness of care during wartime has been a key consideration for hundreds of years. As technological advancements are made, the military continually works to utilize these new developments to provide care to the wounded in a more expedited manner.

World War I

In World War I (WWI) motor vehicles were used in the ambulance corps to transport the wounded to mobile dressing stations or field hospitals.² Following the conflict, many soldiers delivered high praise to the stretcher-bearers who worked fearlessly to carry wounded soldiers through enemy fire to the nearest ambulance.³ Similar to air superiority in later wars, medical teams were able to work more efficiently and effectively when artillery fire was adequately suppressed during times of transport. WWI also presented new obstacles for medical transport personnel in the form of chemical weapons. Medical personnel were exposed to various forms of toxic gases while attempting to provide evacuation services and became victims themselves. Toxic gases became trapped in their clothing and would cause blisters, sores, and other severe health problems which reduced their ability to provide rapid care.⁴ Throughout the war, as patient transport vehicles became more capable and readily available, military doctors worked to ensure wounded soldiers were brought to the operating table within twelve hours of sustaining injuries. By doing so, the risk of infection was reduced and survival rates sharply increased.⁵

Air evacuation remained limited throughout WWI. French engineers and medical professionals adapted French military planes for use as air ambulances.⁶ In 1917, a British soldier in Turkey was shot in the ankle and needed urgent medical attention. He avoided a three

day journey on the ground and was transported by a British air ambulance to a hospital in roughly 45 minutes.⁷ The first recorded occurrence of evacuation using airplanes specifically equipped for patient movement took place in Flanders in early 1918. The United States (US) also began to use airplanes for evacuating patients although initially not as successfully as the French. Because the fuselages were too small to accommodate stretchers, the primary use of airplanes was to transport flight surgeons to various sites in theater to assist with ground transportation.⁸ Also, due to the high rate of airplane accidents during training missions the air ambulance became instrumental in providing care to pilot trainees following a crash.⁹ US military leaders at the close of WWI widely acknowledged the need for aircraft specifically designed to transport the wounded. In 1918, Army officers modified the rear cockpit of a Curtiss JN-4 Jenny biplane to house a stretcher and the first airplane ambulance came into existence.¹⁰ The benefit of an airplane ambulance was not difficult to comprehend and near the end of the conflict the Army directed all military airfields to have an air ambulance.¹¹



Image 1: Curtiss JN-4 used as an air ambulance, Camp Leaside, Ontario, RFC, 1918. (Library and Archives Canada Photo, MIKAN No. 3404545)

Interwar Era

The conversion of the Jenny biplane into an air ambulance led the way for a plethora of medically-oriented aircraft that would soon follow. For instance, the DeHavilland DH-4 aircraft modification provided room for a medical attendant and two patients.¹² Next, the Cox-Klemmin aircraft was constructed, the first airplane designed specifically for use as an air ambulance. In 1921, another aircraft was constructed and named the Curtiss Eagle. This aircraft allowed the transport of four patients on litters as well as six ambulatory patients.¹³ As airplane capabilities and capacities increased sharply, military leaders envisioned more effective employment of aircraft for patient movement purposes. In 1922, a US Army physician predicted the development of airplane ambulances for rapid transport of medical attendants to crash sites, patient movement from remote areas to hospitals, patient evacuation during wartime conditions, and medical resupply. With enhanced technologies came the realization that more robust training was necessary to attend to patients during air transport. As such, Laurretta M. Schimmoler, a registered nurse, was able to establish the Aerial Nurse Corps of America.¹⁴



Image 2: Aerial Nurse Corps of America loading a patient for transport.

World War II

In the early days of World War II, many military medical leaders remained skeptical of the ability and effectiveness of employing aircraft for patient movement. Ground transportation was a more trusted source of patient movement by the Army Medical Department.¹⁵ Although air evacuation had taken place prior to the onset of WWII, many medical experts in and out of the military felt that air evacuation of wounded personnel was “dangerous, medically unsound, and militarily impossible.”¹⁶ The nature of WWII helped those who were resistant to the use of airplanes for patient movement to reconsider. Helicopters had evolved and quickly became an important factor during WWII. During the Hump airlift operation in the remote China-Burma-India (CBI) Theater of Operations, helicopters were used for combat rescue out of simple necessity.¹⁷ Downed planes often landed many miles behind Japanese lines in deep jungle terrain where an airplane could not land. With ground forces over 100 miles away and insufficient roads the only option was to employ the YR-4 helicopter to attempt a rescue.¹⁸



Image 3: R4 Helicopter at National Museum of the USAF.

The first patient was a 21 year old soldier from North Tonawanda, New York. He was informed help was on the way but was unaware that help would be in the form of a helicopter and more than likely was not particular about the method used to rescue him.

The YR-4 helicopter was not very powerful; with only 180 horsepower it could only carry one passenger at a time. But, it was the best option available and due to its success, air evacuations continued throughout the rest of the Hump operation and CBI campaign.¹⁹

The Army Air Forces (AAF) soon utilized transport planes for air evacuation as a secondary mission. In early 1943, with a sharp increase in the overall effectiveness and safety of transport planes, the AAF began transatlantic flights from Prestwick, Scotland, to the US. Later the same year, transpacific flights returned patients to the US through Hawaii.²⁰ Specialized training for personnel involved with patient movement evolved at a rapid pace. As the aircraft became more reliable and technologically sound, so too did the crews operating them. The flight surgeons and nurses taking care of the wounded gained much experience throughout this period. During WWII, the AAF evacuated casualties at a rate of nearly 100,000 per month.²¹ The importance and success of patient movement by air began to be recognized by the majority of those people involved with the war. In the later years of WWII, more than 90 percent of Allied casualties were transported and evacuated by air.²² As the war drew to a close, efforts were made to provide enhanced medical care of patients during transport.²³ General Eisenhower was one of the biggest advocates of utilizing aircraft to evacuate and transport casualties, placing this capability to save lives in the same category as sulfa drugs, penicillin, and blood plasma.²⁴ AAF medical personnel harnessed the great strides made in aircraft technology and medicine simultaneously, and the risk of death during transport dropped to one patient in 200,000 by the

end of the war.²⁵ The effectiveness and efficiency in getting casualties to care in a timely manner proved to be one of the greatest force multipliers of WWII.

Korean War

Even amid the great advancements of decreasing the time to care by utilizing aircraft in WWII, many military leaders still considered ships and ground vehicles as the best tool for patient movement at the onset of the Korean War.²⁶ The lack of speed was obvious, but the overall comfort level and familiarity with ships and ground vehicles led many to favor it over air transport. Because of the difficult terrain, bad weather, and constant enemy fire, Air Force, Army, and Marine Corps rescue helicopters proved vital to evacuating casualties in a timely manner. In essence, the Korean War definitively reinforced the concept that air transport of casualties was often the most efficient method of saving lives even though many had worked to prove otherwise. During the conflict, Air Force H-5 rescue helicopters were employed as frontline medical aircraft and were capable of moving small numbers of casualties in an efficient and effective manner. The Military Air Transport Service (MATs) effectively utilized C-46, C-47, C-54, and C-124 aircraft to transport patients both out of Korea and within the Continental US (CONUS).²⁷ Near the end of the Korean War, the utilization of both fixed and rotary wing aircraft became a well-organized and routine procedure. The fatality rates continued to decrease due to enhanced timeliness of care and streamlined patient evacuation for wounded personnel.²⁸

Vietnam

The importance of decreasing the amount of time to get to medical care continued to evolve in Vietnam. During WWII, roughly 4 percent of the wounded were deceased upon arrival for surgery. With the increased role of helicopters in Vietnam, many of which were specifically used for patient transport, the percentage would be reduced to 1 percent.²⁹ During this conflict,

patient movement from the battlefield to definitive care became a well-organized and streamlined process. The time from injury sustainment to hospitals located in the Philippines and Japan was shrinking considerably. Although the hospital mortality rate was slightly higher in Vietnam compared to Korea, most experts attribute the slight increase to more rapid transport from the battlefield to the hospital. The delayed times in Korea led to many deaths prior to arrival at definitive care when compared to Vietnam.³⁰

Fixed hospitals rearward of the battlefield became more common during this conflict as well which also added to increased rates of survivability.³¹ Helicopters were used to remove casualties from close to the point of wounding. The casualties were then rapidly transported to nearby definitive care where more robust medical care awaited. This patient movement demonstration was coined “scoop and run,” and helped to significantly decrease mortality rates compared to previous conflicts.³² Vietnam proved to be a testament regarding effective utilization of technology to evacuate patients from closer to the point of injury and along with the ability to deliver them to definitive care in limited amounts of time. As helicopter technology evolved with more cargo capacity and effective range medical personnel effectively utilized it to

More Recent Operations

During Operation Just Cause, wounded American military personnel received care at the joint casualty collection point (JCCP) in Panama. The JCCP effectively combined surgical and mobile aeromedical-staging capabilities into one medical element. The JCCP stabilized patients prior to evacuation to military hospitals in San Antonio, Texas. Because of the efficient and effective work of the patient staging teams, along with seamless transition to transport aircraft, the survivability rate was 99.3 percent.³³ Additionally, there were no reported deaths during AE

missions, another sign that both the overall time to treatment and the ability to maintain the status of casualties during transport were improving.

Prior to Operation Desert Storm, US Central Command anticipated the need to care for as many as 15,000 casualties if a contingency erupted in the Middle East.³⁴ Because of the potential for such high numbers of casualties, a robust, patient transport system was implemented to evacuate potential casualties. The Air Force deployed air transportable clinics and hospitals literally hours after the first fighter aircraft deployed in August of 1990.³⁵ Prior to the onset, the AF had equipped contingency hospitals in Germany and England for full operation. The combination of rapid deployability and prepositioned assets ensured evacuation of casualties was not limited early in the conflict.



Image 4: Medical personnel with the Acute Lung Rescue Team begin transporting a patient on extracorporeal membrane oxygenation treatment from Landstuhl Regional Medical Center, Germany, to the San Antonio Military Medical Center, Texas. This was the first time the military moved an ECMO patient such a distance. Source: Stripes.com July 14, 2013.

During Desert Shield/Desert Storm, nearly 13,000 patients were evacuated on 671 flights with no casualties. The robust footprint of the many different medical facilities allowed for a near flawless execution of patient movement with many complicated patient cases transported over long distances with great care.

Current Capabilities

Recent operations in Iraq and Afghanistan also rely heavily on air superiority for patient movement operations. In addition to air superiority requirements, advanced medical teams and more highly trained medics are located closer to the fight to allow earlier and more heavily involved intervention. As a result, casualty rates over the last decade of war are the lowest in the history of armed conflict.³⁶ When the “Golden Hour” initiative was instituted in Iraq, many felt it was simply unrealistic to transport casualties to advanced treatment facilities in less than 60 minutes. However, it soon became apparent not only was it possible, but in most cases the “Golden Hour” was met. In Afghanistan, due to the high altitudes of the mountainous area where fights were taking place, the standard was roughly two hours; which was not sufficient time for many combat related injuries. In late 2009, Secretary of Defense Robert Gates travelled throughout the region and promised troops he would do everything in his power to bring the “Golden Hour” to Afghanistan.³⁷ Even with the best technology that the helicopter community has to offer, there are certain areas of Afghanistan that are difficult to reach in a timely manner.

Over the past decade, medical care in Iraq and Afghanistan has become a robust and streamlined system. The Army “Dustoff” helicopter crews, along with USAF HH-60G Pave Hawk helicopters, reach out to forward operating locations throughout the region to transport casualties back to Bagram Airfield.³⁸ Bagram Airfield has robust medical capabilities along with enhanced stabilization facilities to prepare patients prior to further evacuation. Another key to

recent success involves increased awareness and acute care training for frontline battlefield personnel. Essentially, moving more highly trained personnel closer to the fight has helped to decrease battlefield fatalities.

Another recent advancement in patient movement and battlefield care is the creation of aeromedical evacuation teams to address gaps in the frontline medical care in Africa. Most US forces operating in Africa are small Special Forces Units (SFU) with a limited footprint accentuating their capability to perform missions in remote areas the continent on little notice. This can present challenging problems for medical personnel performing stabilizing procedures prior to patient evacuation. Often times these units are severely isolated from organic medical facilities with advanced surgical capabilities, as well as adequate host nation hospitals.

The USAF has been working to create a capability that would mitigate much of the risk associated with performing operations outside traditional in-place medical facilities. The US Air Forces in Europe (USAFE) found a solution with the creation of the Tactical Critical Care Evacuation Team – Enhanced (TCCTE-E). This allows USAF medical teams to remain in a ready position with the capability to evacuate and transport unstable patients from near the point of injury back to Europe.³⁹ These advanced medical teams have the capability to perform surgeries both prior to takeoff and during transport as well. This capability allows surgical teams to transport casualties prior to being stabilized, something that is highly unlikely to happen in Iraq and Afghanistan.⁴⁰ Although not ideal, it provides additional options for those units operating in austere and remote locations at a long distance from higher echelons of medical care. It does require a significant degree of air superiority to perform these long distance evacuations aboard aircraft such as a C-130 or C-17.

Challenging Future Operating Environments

In future operating environments, the ability to gain air superiority and quickly infill combat support assets to locations necessary to project power may not be feasible. Adversaries are becoming increasingly capable of employing Anti-Access/Area Denial (A2/AD) strategies against the US and coalition forces. A2/AD strategies seek to limit the US and allied forces' ability "to get to the fight and to fight effectively once there."⁴¹ The proliferation of missile arsenals of potential adversaries allows aggressive actors to potentially employ A2/AD tactics against the US with increasing success. Missiles arsenals are becoming progressively more accurate and lethal with improved ranges compared to previous weapons.⁴² Various weapons systems can be employed with little or no notice such as cruise, ballistic, air-to-air, and surface-to-air missiles.⁴³ Many overarching warfighting documents, such as the Joint Operational Access Concept (JOAC) and the Joint Concept for Entry Operations (JCEO) seek to integrate forces to allow sufficient control of warfighting domains.⁴⁴

The US and allied forces have a long history of overcoming threats and geographic challenges with the use of forward bases to ease the deployment burden.⁴⁵ Combat operations in A2/AD environments will likely limit the ability to utilize far forward bases. Additional factors must be considered such as the distance from the homeland to the operational area, the distance inland from navigable waters to the objective area, and the nature of the climate and terrain in the operational area.⁴⁶ These are a few of the factors that make it difficult to develop plans to conduct effective combat operations in A2/AD environments.

A2/AD environments primarily impacts the ability of medical units to persist in a location long enough to properly stage casualties prior to transport. Adversary A2 capabilities seek to limit the ability of US and allied forces to deploy sufficient combat support assets into

the theater of operations, which can have an impact on timely medical care by influencing the location of facilities. Adversary AD impedes the ability to maneuver once in theater, and impacts medical care by limiting the ability of transport assets to persist in a specific location long enough to provide support to combat forces.⁴⁷

In response to increasing missile arsenals and threats US military planners have developed specific strategies to counter A2/AD threats. The Forward Air Base Operations (FABO) concept was developed to provide a way to operate airbases and allow power projection within enemy missile strike ranges.⁴⁸ In order to project power from inside the strike ranges specific assets must possess a much smaller footprint and be able to relocate in short notice. This flexible type basing system creates additional dilemmas for patient transport and the ability to provide robust surgical intervention services in a timely manner. Operating inside missile threat rings also pose higher risks of casualties on a much larger scale compared to recent conflicts in the Middle East.

Due to the aforementioned concern, military leaders must develop patient movement platforms that focus on not only saving lives, but survivability on the battlefield. Other important factors to consider must include the number and type of potential casualties, the area of denied and/or contested terrain, the distance to echelons of care, and the feasibility of air superiority. Just as Africa presents difficulties in providing medical care to SFUs operating in remote austere locations, other areas around the globe pose similar problems. While much of the recent analysis has focused on areas in the Pacific AOR, similar challenges exist in Africa. The current patient movement system, (i.e., the system in place that systematically and linearly moves stable patients from point of injury to higher echelons of care) is well suited for the limited conflicts currently taking place in Iraq and Afghanistan. With air superiority, medical

forces can infill robust medical facilities and stage patients prior to transport very near to combat areas. However, in more complex operating environments, particularly in heavily contested and/or denied environments, the linear system is likely to fail. It is highly possible that an insufficient number of treatment facilities near the point of attack will exist.⁴⁹ Additionally, situations may occur where airlift assets are simply not available, or are severely limited compared to the number of casualties requiring care and transport.⁵⁰ In essence, the goal remains to transport patients to higher echelons of medical care within 60 minutes, but medical teams are expected to perform the mission with fewer personnel, a lighter overall footprint, and from distances further from the frontline when compared to Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) and with more survivable assets.⁵¹

Patient Mortality Risk Assessment Matrix			Highest Level of Care Available To Severely Injured Patient				
			1 – Minimal	2 – Minor	3 – Moderate	4 – Major	5 – Significant
			SABC	Medic	FST	Field Hospital	Theater Hospital
Patient Movement Probability	A -	May occur but only in rare and exceptional circumstances	Extreme Risk	Extreme Risk	Extreme Risk	High Risk	Moderate Risk
	B -	Unlikely to occur but could happen	Extreme Risk	Extreme Risk	High Risk	Moderate Risk	Moderate Risk
	C -	Possible and likely to occur at some time	Extreme Risk	High Risk	High Risk	Moderate Risk	Low Risk
	D -	Likely to occur frequently	High Risk	High Risk	Moderate Risk	Moderate Risk	Low Risk
	E -	Almost certain to occur	Moderate Risk	Moderate Risk	Moderate Risk	Low Risk	Low Risk

Figure 1: Patient Mortality Risk Assessment Matrix adapted from MODE v1.0. This demonstrates the probability of patient movement and to what level of care.

As mentioned previously, due to the potential for short and/or no notice attacks from adversaries, the ability for medical personnel to preposition and infill medical assets will likely be restrained. Without this capability, considerably higher casualties can be expected along with significantly longer wait times for treatment. Another dilemma this specific situation creates is disruption of medical resupply chains. Other medical considerations that arise from combat operations in A2/AD environments are: degraded AE staging operations associated with damaged airfields, airfield battle damage that impedes intra and inter-theater casualty evacuation, and longer patient hold times will drive increased patient bed requirements.

(Figure 1) illustrates the point that as the probability of patient movement decreases, the risk of inadequate life-saving capabilities increases. Ultimately, whenever potential adversaries successfully employ AD techniques, alternate methods of patient care and movement must be implemented to minimize fatalities.⁵² This is particularly true when one considers the overall lack of airframe availability while operating in heavily contested and denied environments.

Another concern that may limit the ability to care for and evacuate casualties in future environments is the use of Chemical, Biological, Radiological, and Nuclear (CBRN) weapons. If CBRN weapons are employed, in particular while performing combat operations in denied environments with limited air asset availability, commanders must determine the quantity and type of uncontaminated resources that will be introduced into the contaminated environment.⁵³ In this type of environment, commanders are directed to evacuate casualties in a timely manner while working to ensure that the least number of assets becomes contaminated during the process.⁵⁴ Air assets are typically much more difficult to decontaminate when compared to ground evacuation vehicles. For this purpose, commanders are directed to utilize ground vehicles where possible. During combat operations in A2/AD environments, particularly in

areas throughout the Pacific, ground vehicles are likely to be very limited in availability. With ground vehicles limited and sea assets often at great distances from combat operations, air assets will be required to evacuate casualties from CBRN environments. However, with limited availability, commanders will potentially be hesitant to allocate uncontaminated air assets for the purposes of patient movement.

Potential Solutions

Future operating environments pose great challenges to the US and its allies in caring for and evacuating casualties in a timely manner. Based on this history, combined with overarching policy directives that predict the need to conduct operations in A2/AD environments, the US must work to test and develop alternate means of evacuating casualties. When manned assets are denied entry or simply unavailable due to mission requirements, the use of unmanned assets could be a natural evolution in utilizing new technologies for patient movement. While other methods require air superiority to remain viable, unmanned assets offer the potential to continue patient movement operations until air superiority is restored. The most lifesaving benefit can be obtained if this capability is tested and developed prior to being forced to utilize it prematurely during a future conflict.

The operational military has shifted to training more unmanned aircraft pilots than manned aircraft pilots.⁵⁵ UAV operations continue to improve in safety as well. The US M/RQ-1 Predator accident rate is significantly less than the US F-16 rate.⁵⁶ Currently, nearly 1/3 of US military aircraft are unmanned. The US Army formulated a UAV roadmap and included statistics that predict 35 percent of all cargo missions will be flown by UAVs by 2020. Additionally, by 2025, the Army predicts that Optionally Piloted Vehicles technology will be on board the entire inventory of rotary-wing aircraft.⁵⁷

Combat support services such as medical must continually evolve alongside operational military developments and the transition to higher utilization of UAVs is no different. Many Department of Defense future concept and policy documents recommend exploring additional uses for unmanned aerial vehicle (UAV) platforms. For instance, in recent guidance released by the AF Vice Chief of Staff, the AF Surgeon General (AF/SG) was directed to deliver an assessment on enhanced forward surgical and en-route clinical capabilities for the “next conflict.”⁵⁸ This assessment, according to the Vice Chief, must include future requirements to enable operations in A2/AD environments.⁵⁹ In addition, recent guidance released from the AF/SG futures directorate suggests “patient movement will require enhanced utilization of non-traditional evacuation/treatment platforms.”⁶⁰ In this regard, the ability of the AF to adapt and respond faster than potential adversaries is considered the greatest challenge of the next three decades.⁶¹

In order to “adapt and respond” in terms of patient movement and evacuation the military must work toward utilizing UAVs for casualty evacuation. A recent NATO study and report concluded that the employment of UAVs “for casualty evacuation will soon be a reality and eventually commonplace in the battle space.”⁶² UAVs were initially utilized for intelligence, surveillance, reconnaissance, and targeting missions.⁶³ However, UAVs are now being designed and used for a plethora of purposes beyond those original uses. As demonstrated previously, circumstances are likely to occur where traditional assets are unavailable for patient evacuation. Long delays which cause increased casualties are likely unless unconventional platforms are utilized. There certainly exists a long list of factors to be considered if this is to become an available solution. In turn, this capability will not replace the system currently in place, but should augment traditional lifesaving options employed by combatant commanders.

The most likely scenario where UAV patient movement will be employed is in operating environments where traditional MEDEVAC has not been established.⁶⁴ For casualties with hemorrhage wounds, even with forward surgical teams in the field, the time to higher echelon levels of surgical intervention is the most crucial element in terms of survival. Some key advantages that UAVs offer in comparison to traditional manned assets include:

- Greater speed and availability over ground vehicles.
- Ability to operate in adverse conditions.
- Increased risk tolerance while flying in hostile environments.
- Improved ability to land in unprepared landing sites. (Autonomous landing platforms are currently being tested for use on battlefield.)
- Increased risk tolerance to evacuate casualties from CBRN environments.⁶⁵

Long before UAVs are utilized for casualty evacuation, research must determine the necessary and appropriate physiological parameters to allow for safe transit. For this purpose, medical combat developers must become involved in the design process from early phases. If this takes place, fewer unknowns will be apparent in future operations where this may take place.

A step-wise approach must be taken to minimize delays and maximize future capabilities of UAV patient movement. Near, mid, and long range planning considerations need to be accounted for. In the near term, research must take place regarding remote delivery of medical supplies (i.e., equipment, blood, supplies). Researchers must be able to demonstrate feasibility, establish delivery reliability rates, and develop key performance parameters (KPP) for class VII (medical) resupply. In the mid-range (next 5-10 years), studies and research must focus on the transport of stable patients. Information vital to the capability includes: specification of what types of injuries qualify a patient as stable, refinement of safe ride standards and guidelines,

identification of the most reliable telemedicine capabilities to be used during transport, and ethical considerations. Long term research and development (10-20 years) must take place to determine the feasibility of UAV patient movement in conjunction with an on board medical specialist. Additionally, research alongside combat developers is necessary to determine the feasibility of increased platform capacity (i.e., weight and space requirements for a minimum of two people). During this phase, research will need to be conducted for KPPs to potentially allow movement of unstable patients using UAVs. In the far distant term (20+ years), determinations will need to be made regarding casualty movement without a medical specialist. Over the next two decades, closed loop and autonomous telemedicine capabilities are expected to exponentially increase. These systems must be tested and adapted to the battlefield. Robotics will need to be further evaluated to consider in flight intervention not in conjunction with manned actions.⁶⁶



Figure 2: Potential UAV Resupply/Patient Movement Scenario, Adapted from: Lam, Gilbert, Michael Beebe. *Unmanned Aircraft Systems for Casualty Evacuation-What Needs to be Done*. From Mode v1.0

This step-wise, phased approach is likely the best avenue to allow the most realistic and safe approach to the eventual use of UAVs for patient movement. Ultimately, a scenario depicted in the UAV patient movement diagram (Figure 2) will take place.

Many ethical considerations need to be considered prior to this scenario actually taking place. A recent NATO report recommended some key considerations that must be accounted for:⁶⁷

- The aircraft must meet all the same safety-of-flight requirements as do current manned Rotary Wing Aircraft.
- Environmental Standards in the casualty compartment (e.g. noise, vibration, acceleration factors, and air quality) must be met in accordance with current standards.
- Some provision must be made to fix the casualty to the aircraft (e.g. litter tie-downs).
- Carriage of the casualty must be internal to the aircraft.

Although this list is not comprehensive, it includes many of the key considerations that leading experts have compiled. Some additional findings that were presented in the report discuss the very real probability that this technology will take place in the near future. For instance, the report concludes that the “use of UAVs for casualty evacuation in the short to medium term (5-15 years) will be both practical and likely, and in certain operational scenarios may prove to be the only practical option available.”⁶⁸ The report also concluded that as soon as resupply UAVs or optionally-piloted conventional aircraft are readily available on the battlefield they will be utilized for patient movement. The important factor stressed in the report is the urgent need for the medical community to ensure when it happens, not if, it is as safe as possible.⁶⁹

Virtual Care as a Force Multiplier

Telemedicine and remote tele-monitoring offers additional solutions to leverage care remotely.⁷⁰ As mentioned previously, with potentially fewer medical assets and personnel near the frontline, the Department of Defense (DoD) must research additional methods that can serve as a force multiplier in heavily contested and denied environments. Although fewer medical personnel are expected to be on the battlefield, the “Golden Hour” standard will likely remain a priority for commanders. A 2012 study researched battlefield mortality data from 2001-2011. The study revealed most battlefield deaths took place prior to reaching a surgeon.⁷¹ Three major takeaways from the study included: strategies must be developed to mitigate hemorrhage, to optimize airway management, and to reduce the time interval between the point of injury and surgical intervention.⁷²

Advanced telemedicine, when combined with future UAV casualty evacuation capabilities, has the potential to address all three of the aforementioned needs. Other concurrent studies to address some of these needs are also ongoing. For instance, a prototype dynamically balanced bipedal Battlefield Extraction Assist Robot (BEAR) is being developed that can extract up to a 350 pound casualty from rugged terrain.⁷³ Another project sponsored by the Department of Defense seeks to “exploit UAVs to bring sophisticated telemedicine and patient monitoring equipment such as “smart stretchers’ directly to military medical first responders and troops engaged in combat.”⁷⁴ The DoD is making great strides in order to more effectively utilize unmanned technology to both mitigate risk and increase the number of troops at the same time.

Conclusion

The ability to effectively utilize new technology to decrease the time to provide necessary medical and surgical intervention has long been the goal of both medical and military

commanders alike. This paper demonstrates a consistent theme of technological advancements being utilized to decrease the time to care and ultimately save lives. The natural evolution and the logical next step of seeking the best method to reduce time to care must certainly involve UAVs. As adversaries of the US and its allies gain additional and enhanced warfighting capabilities, the need to employ this capability will most likely increase exponentially. The remaining question is not if UAVs will be used for patient movement, but when. There are many different steps that must take place to ensure safety for patients prior to this happening. However, by using a step-wise, phased approach it lies within the realm of possibility that the DoD can research, develop, and ensure the overall safety of UAV patient movement in the near future. In the end, it is going to happen; we might as well make it safe.



Notes

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